Fiber To The Home: Technology Competition and Industry Structure

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**Presented at the Madrid Meeting of the
M.I.T. Internet Telecommunications Convergence
Consortium, June 17, 2002**

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FTTH: Summary of the Argument

? **Competition should not be limited to those who own a fiber into the home**
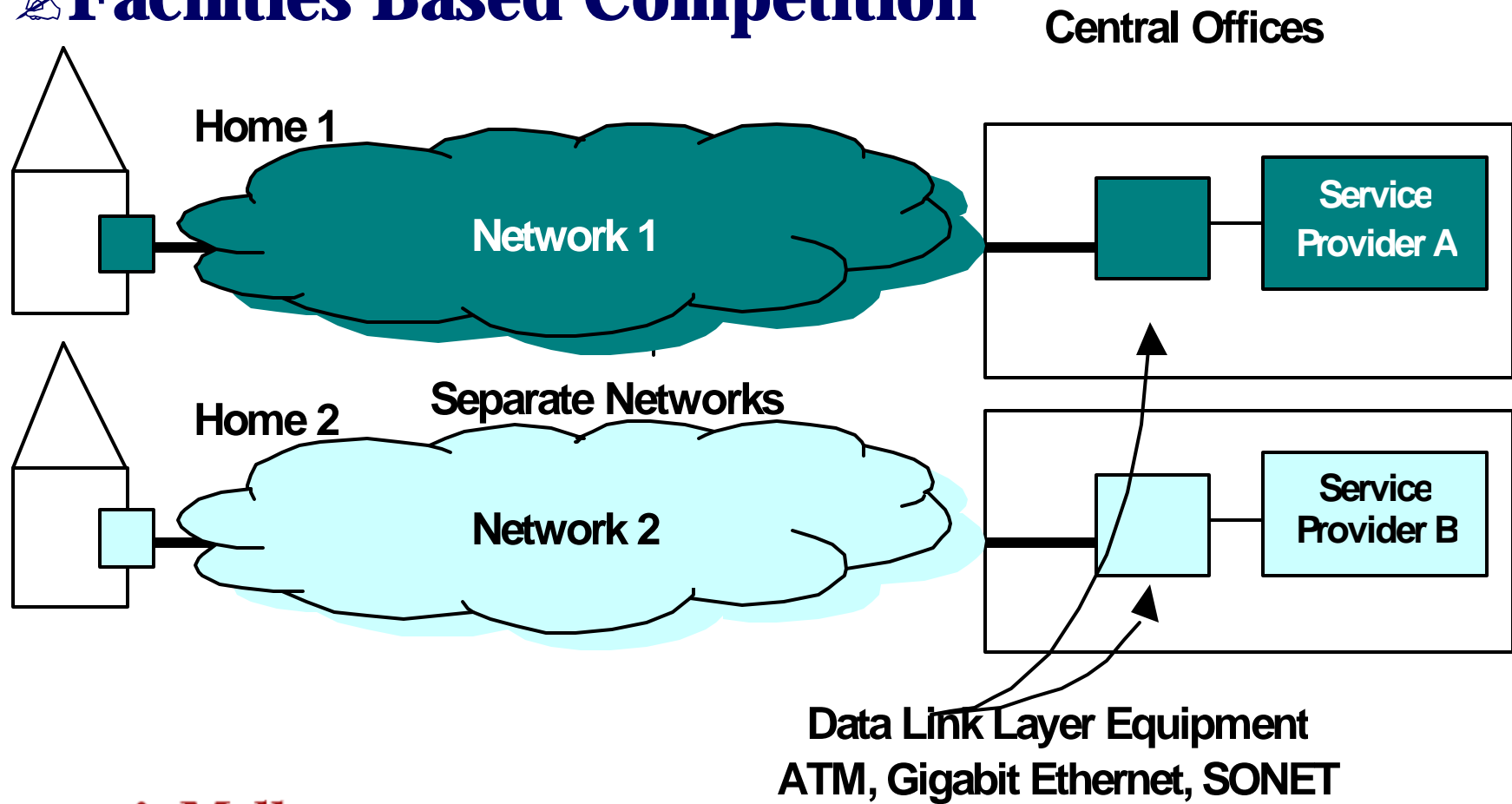
? **Competition can be over:**

- A shared dark fiber network
  - Physical layer unbundling or 'UNE based competition'
- A shared data transport network
  - Logical layer unbundling or 'Open Access based competition'

? **Fiber network layout affects:**

- The costs and flexibility of service roll-out
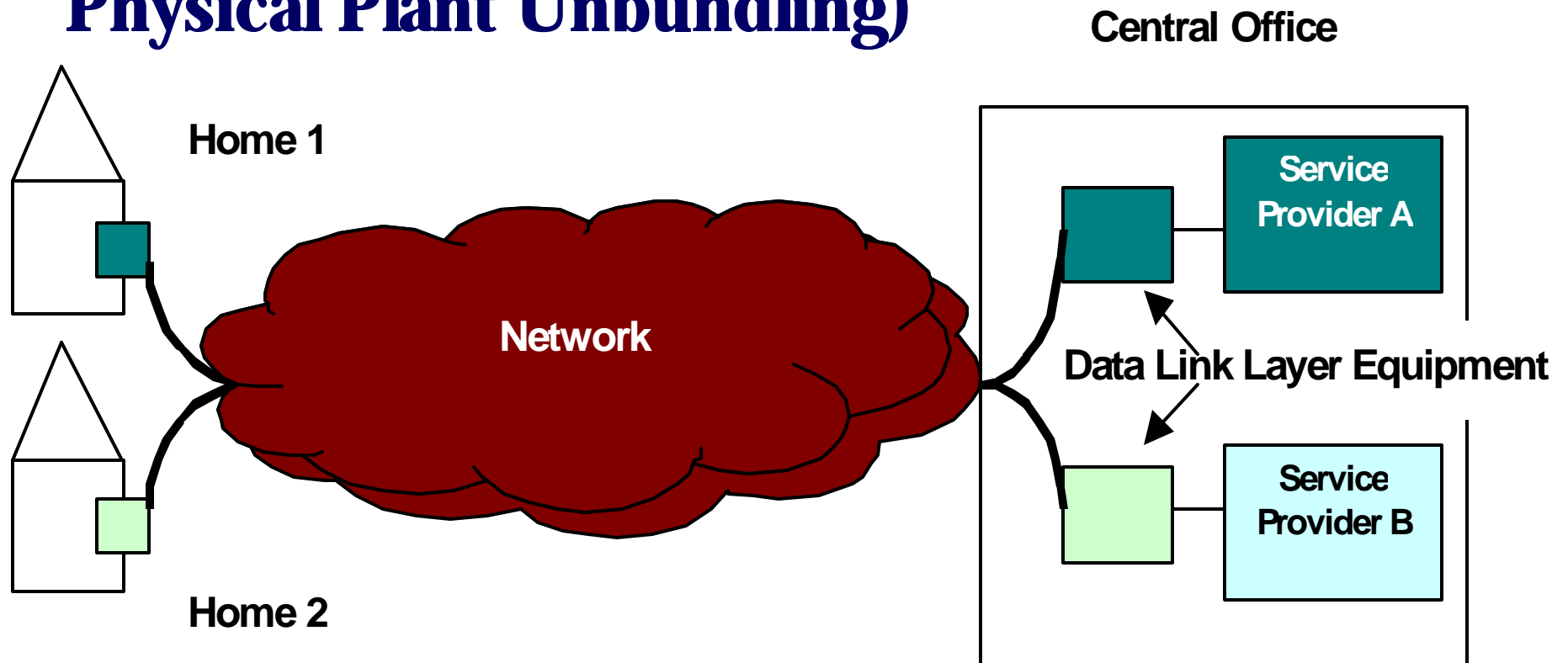- The potential for UNE competition

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Models of Competition in Telecommunications

? **Facilities Based Competition**

Central Offices

Home 1

Network 1

Service Provider A

Separate Networks

Home 2

Network 2

Service Provider B

Data Link Layer Equipment
ATM, Gigabit Ethernet, SONET

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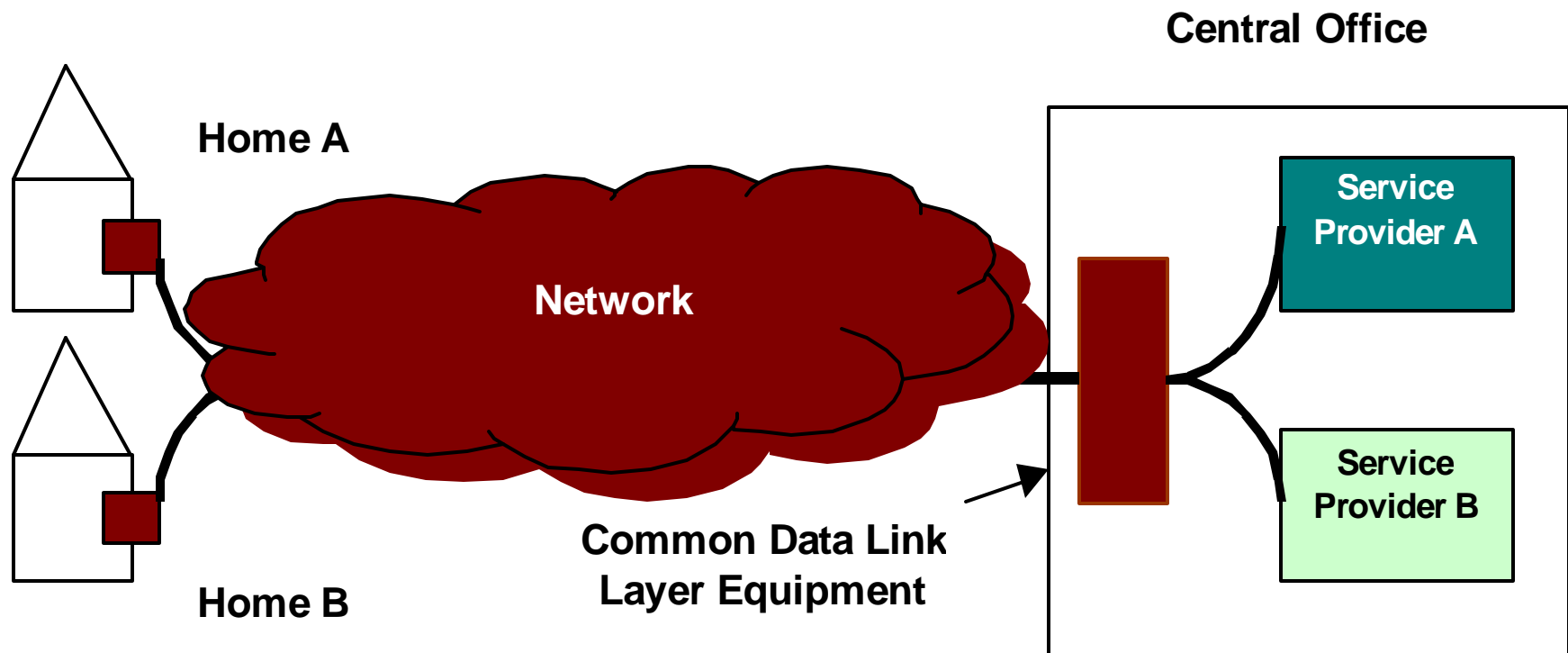# Models of Competition in Telecommunications

? **UNE Based Competition (made possible by Physical Plant Unbundling)**

Central Office

Home 1

Network

Data Link Layer Equipment

Service Provider A

Service Provider B

Home 2

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Models of Competition in Telecommunications

?**Open Access Based Competition (made possible by Logical Layer Unbundling)**

Central Office

Home A

Network

Home B

Common Data Link Layer Equipment

Service Provider A

Service Provider B

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Models of Competition in Telecommunications

UNE Based Competition AND Open Access

Central Office

Home 1

Network

Service Provider A

Service Provider C

Service Provider B

Home 2

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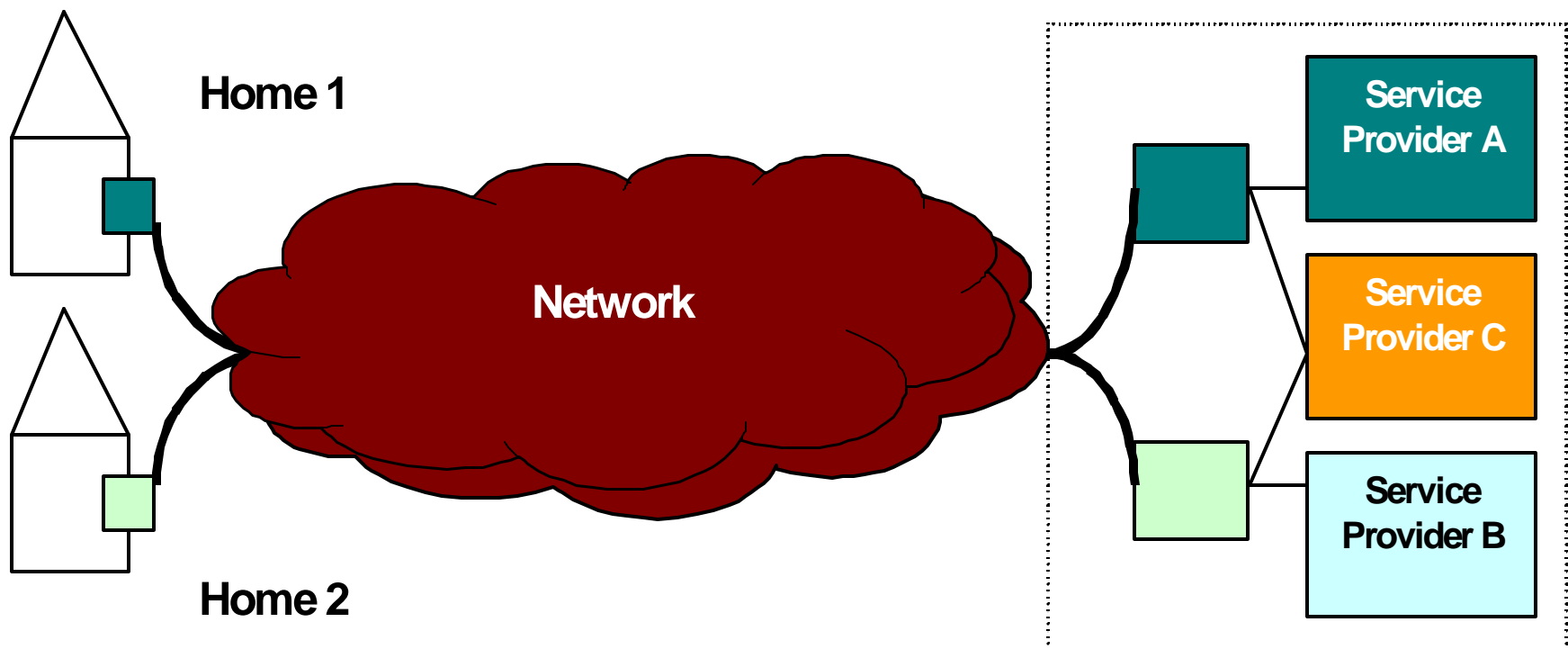
Why Open Access is Not Enough

- **Physical plant monopoly extended to data-link layer monopoly**
- **All services must run over a common, standardized, data-link layer**
  - Even if some subscribers want ATM and some Gig-E
- **Limits data-link layer technology evolution**
- **Service possibilities limited by data-link layer capabilities**
- **Policing QoS provided to open access competitors is hard**

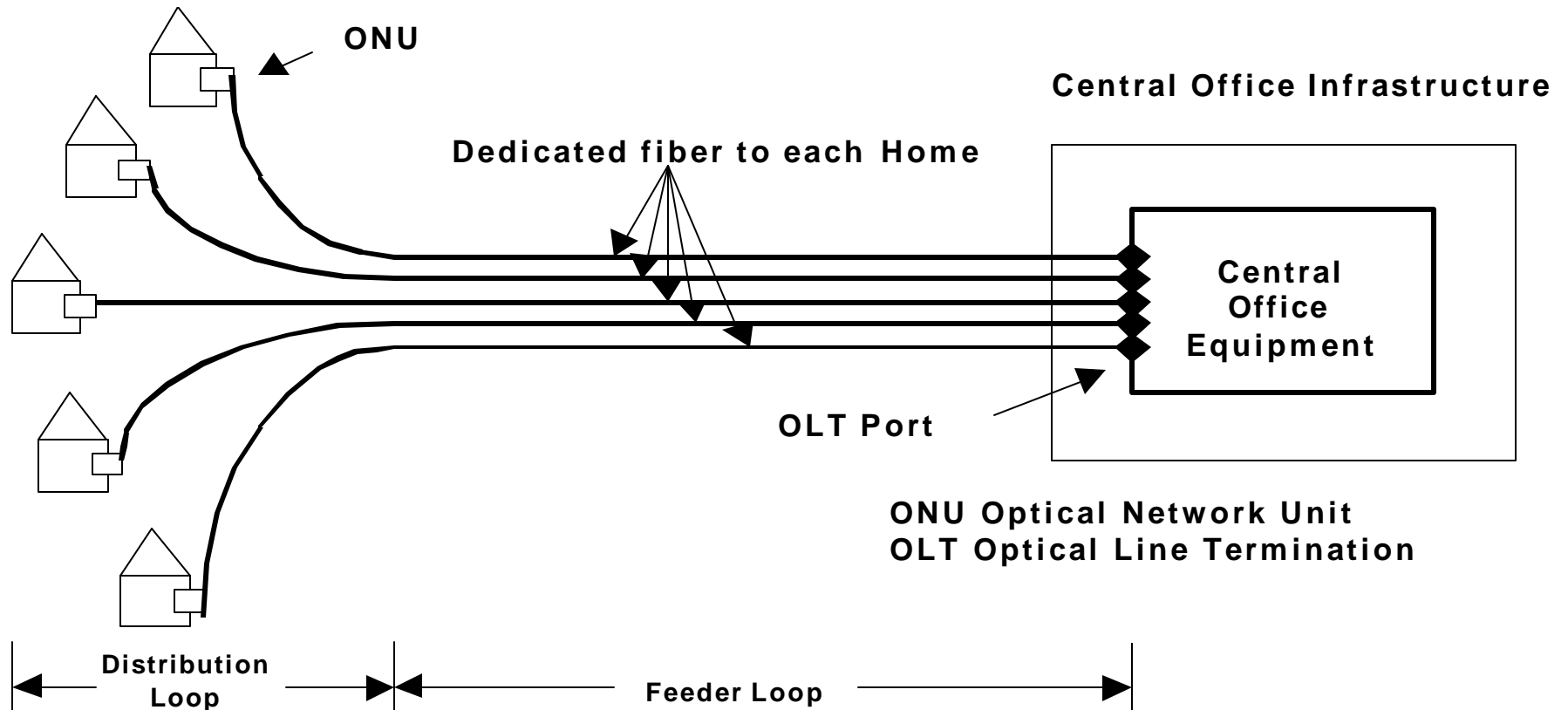**Carnegie Mellon**

FTTH Architectures

- **Home Run**
- **Active Star**
- **Passive Star (Passive Optical Network - PON)**
- **Wavelength Division Multiplexed Passive Optical Networks (WDM PON)**

Home Run Architecture

ONU

Central Office Infrastructure

Dedicated fiber to each Home

Central Office Equipment

OLT Port

ONU Optical Network Unit
OLT Optical Line Termination

Distribution Loop

Feeder Loop

Architecture	Brief Description	Shared Infrastructure
Home Run	Dedicated fiber from the Central Office to each Home	Central Office

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Active Star Architecture

ONU

Central Office Infra structure

Shared Feeder fiber

1

Central Office Equipment

32

OLT

Remote Node with Active Electronics Equipment

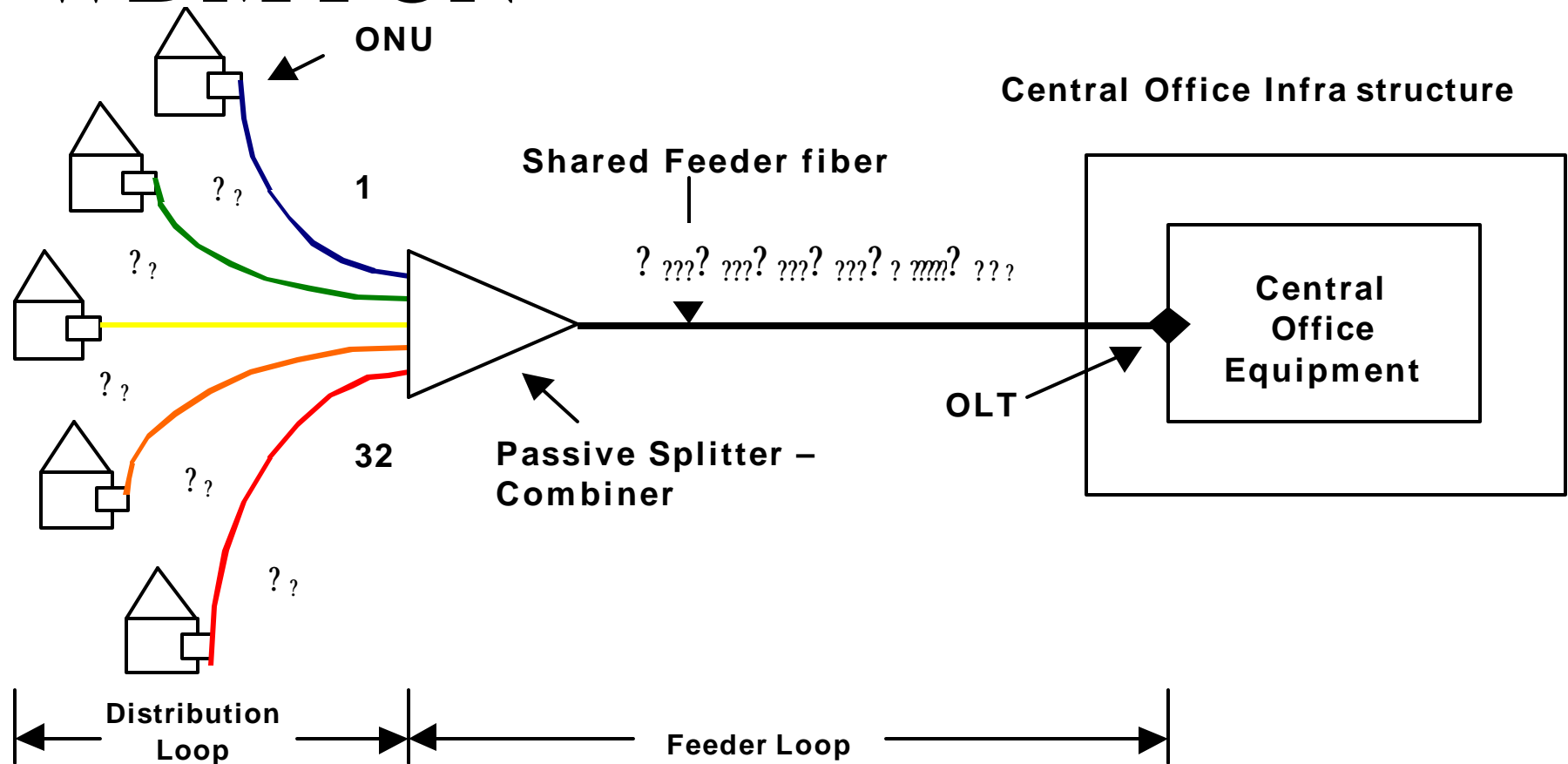|← Distribution Loop →|←——— Feeder Loop ———→|
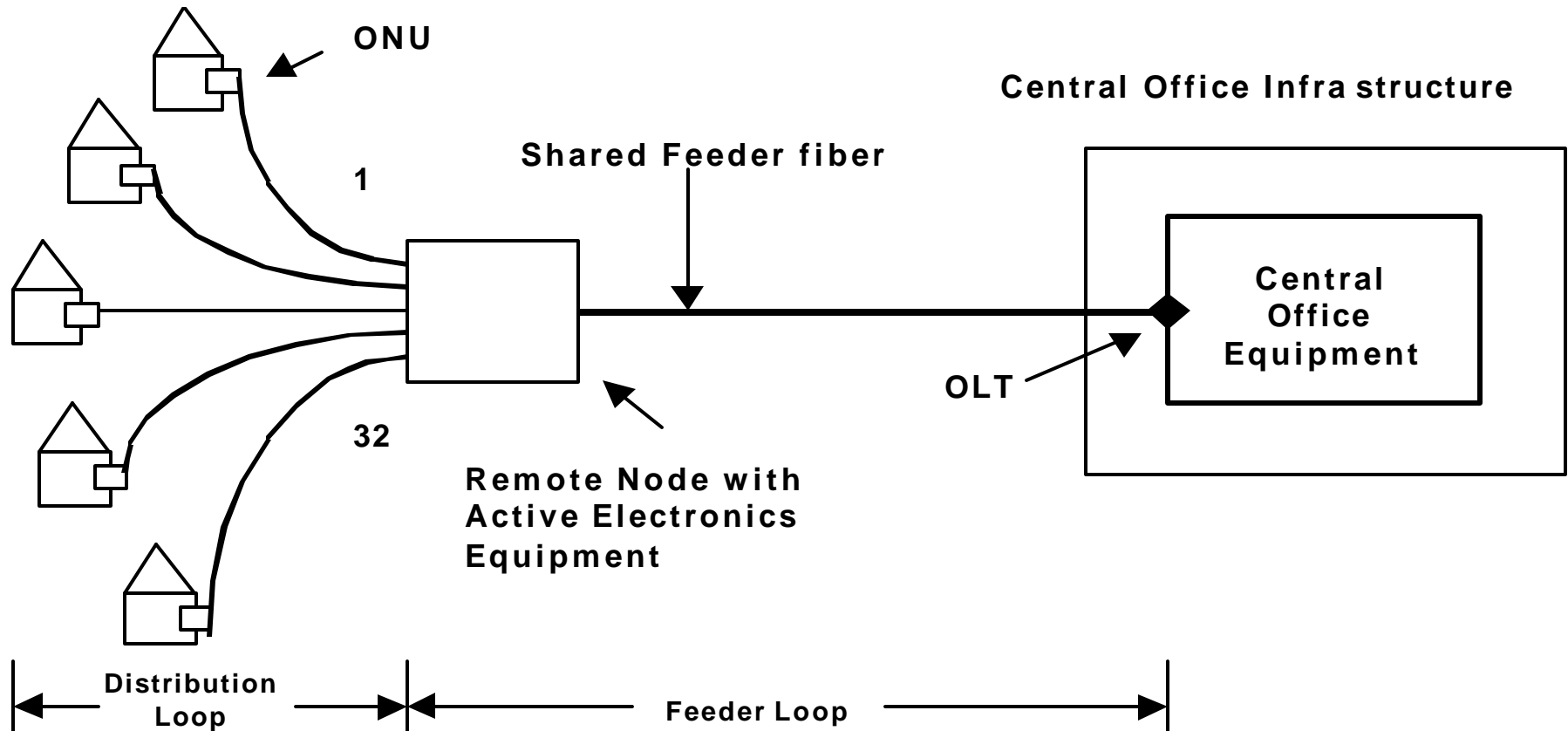
Architecture	Brief Description	Shared Infrastructure
Active Star	Signals multiplexed at Remote Node that lies between Central Office and Home	From theCentral Office to the Remote Node

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Passive Star Architecture (PON)
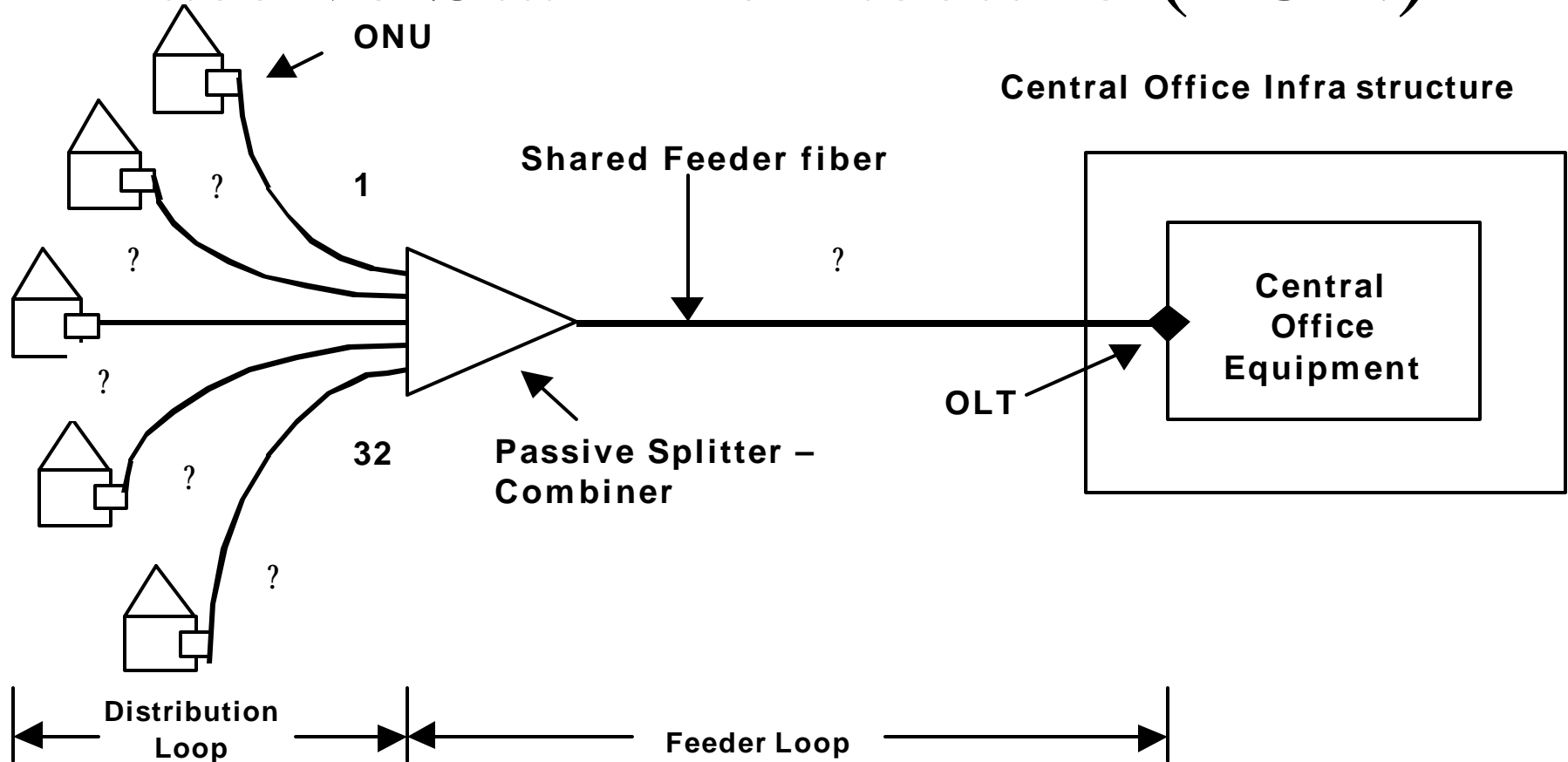
Architecture	Brief Description	Shared Infrastructure
Passive Star	Signal's power optically split at Remote Node; Remote Node not powered	From Central Officet to Remote Node

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WDM PON

ONU

Central Office Infra structure

Shared Feeder fiber

1

32

Passive Splitter – Combiner

OLT

Central Office Equipment

Distribution Loop

Feeder Loop

| Architecture	Brief Description	Shared Infrastructure
WDM PON	Signal's power optically split at Remote Node; Feeder fiber carries multiple wavelengths	From Central Officet to Remote Node

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Economics of FTTH

- ✍ **We have built an engineering cost model to examine the economics of FTTH networks**

  - Understand economies of scale

  - Compare architectures

Engineering Cost Model

- **Four Architectures**
  - **Home Run Fiber**
  - **PON**
  - **Active Star**
  - **WDM PON**

- **Aerial Fiber**

- **Five Deployment Scenarios**
  - **Urban**
  - **Suburban**
  - **Small Town**
  - **Rural**
  - **Remote Rural**

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Cost Model
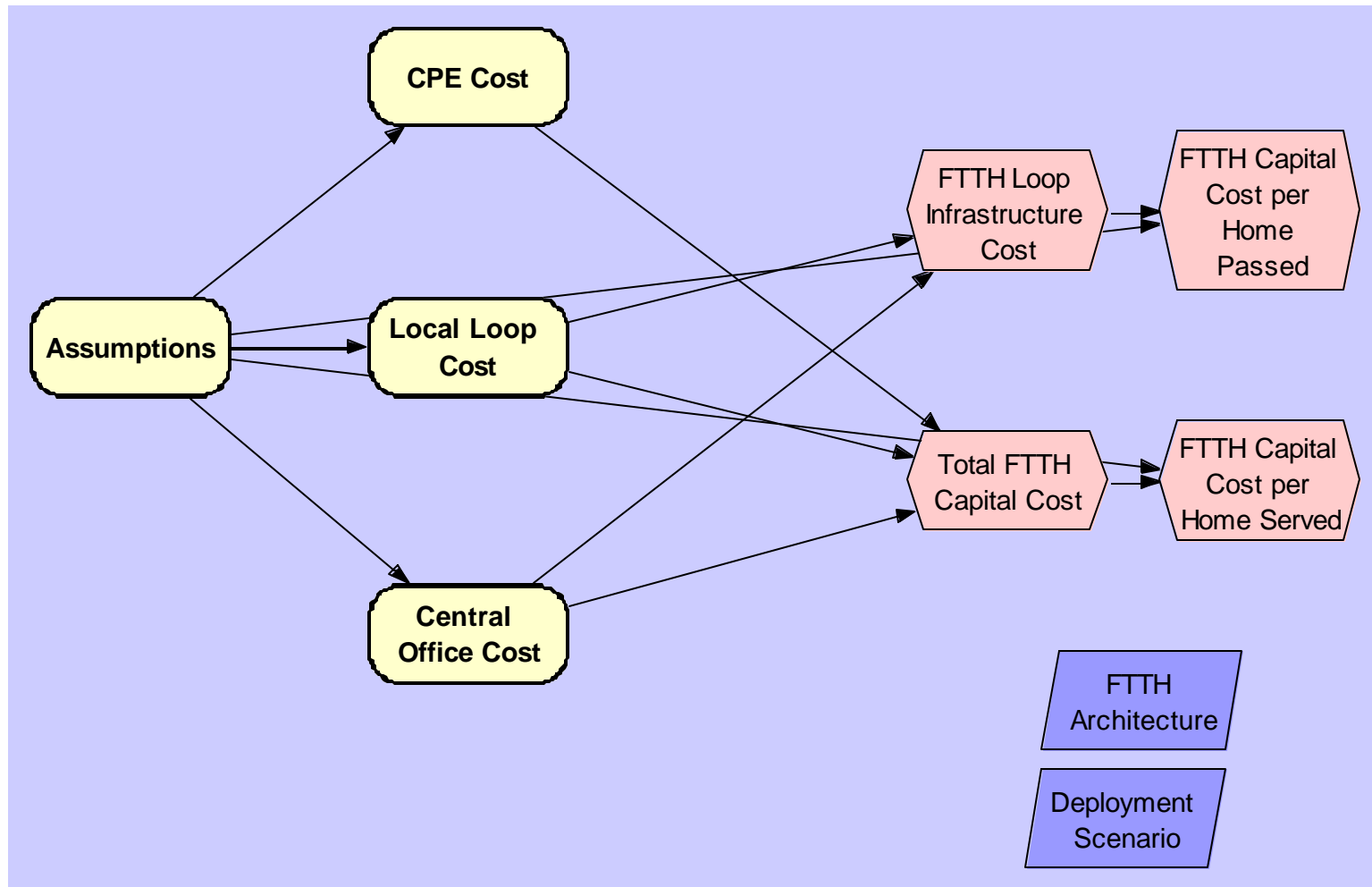
Data from HAI Model 5.0 A

Central Office (CLLI)	No. of Clusters	Total no. of Homes	Housing Density (Homes/sq. mi.)	Average Radial Distance from CO to each cluster (ft)
PITBPASQ (Urban)	23	16,135	3,389	4,730
HMSTPAHO (Suburban)	23	16,201	1,603	9,089
CHTTPACT (Small Town)	14	10,184	218	15,165
TNVLPATA (Rural)	10	5,871	86	18,662
CCHRPAXC (Remote Rural)	18	3,018	20	32,763

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FTTH Engineering Cost Model

Architecture	OLT Interface
Home Run	100 Mbps Fast Ethernet per Home
Active Star	Gigabit Ethernet Interface per 32 Homes
PON	Gigabit Ethernet Interface per 32 Homes
WDM PON	100 Mbps Fast Ethernet per Home

ONU Interface
2 POTS ports, 10/100 Base T, RF Video

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FTTH is a decreasing cost infrastructure..

Capital Cost per Home Served (Urban Deployment)
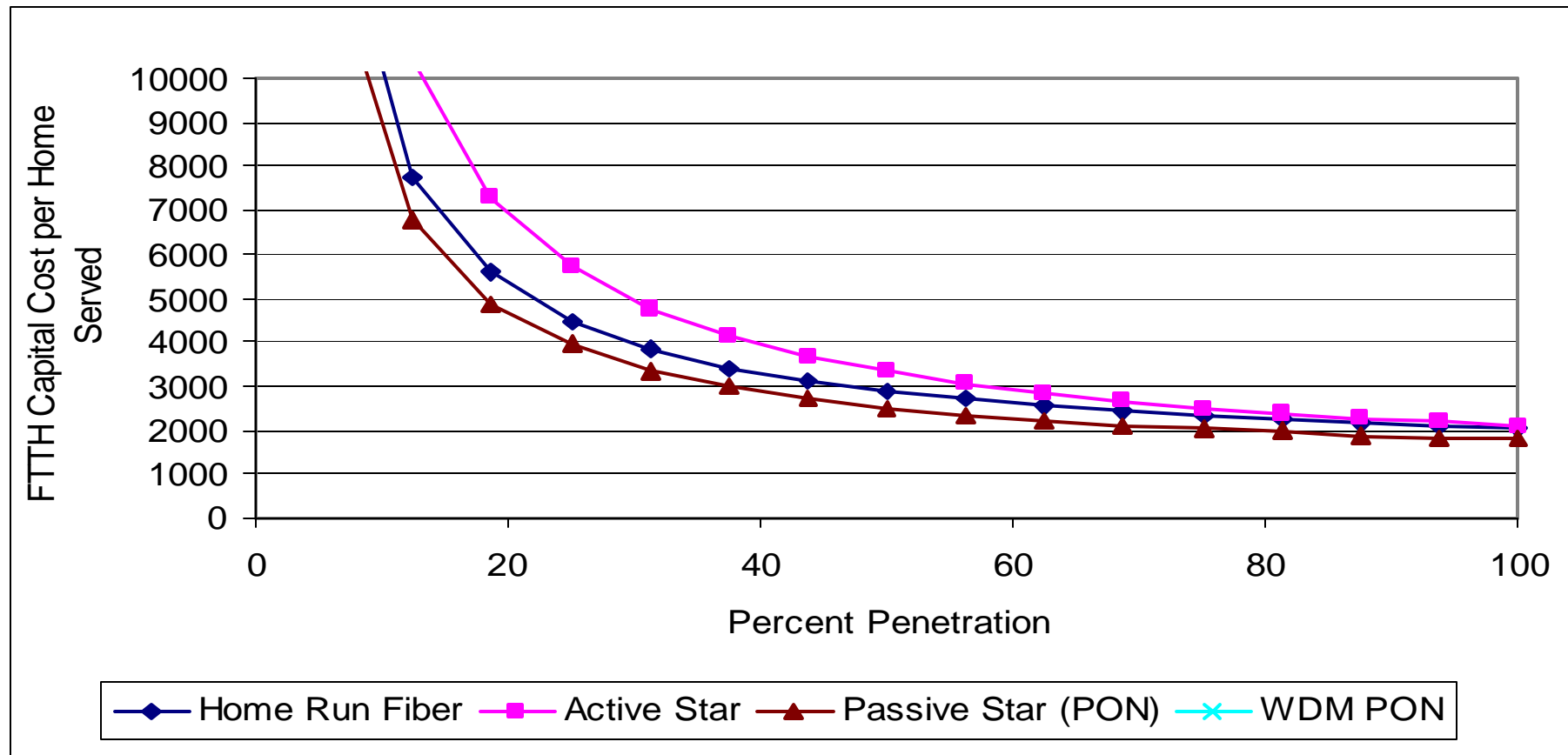
..Facilities based competition is unlikely in FTTH

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Fiber Loop Cost Breakdown (Home Run Fiber)

Capital Cost per Home Passed (Home Run Fiber)

Legend:
- Feeder Loop
- Distribution Loop
- Central Office Building
- Pole Make Ready Costs

Y-axis: USD per Home (0.0, 1000.0, 2000.0, 3000.0, 4000.0, 5000.0, 6000.0)

X-axis (Deployment Scenario): Urban, Suburban, Small Town, Rural, Remote Rural

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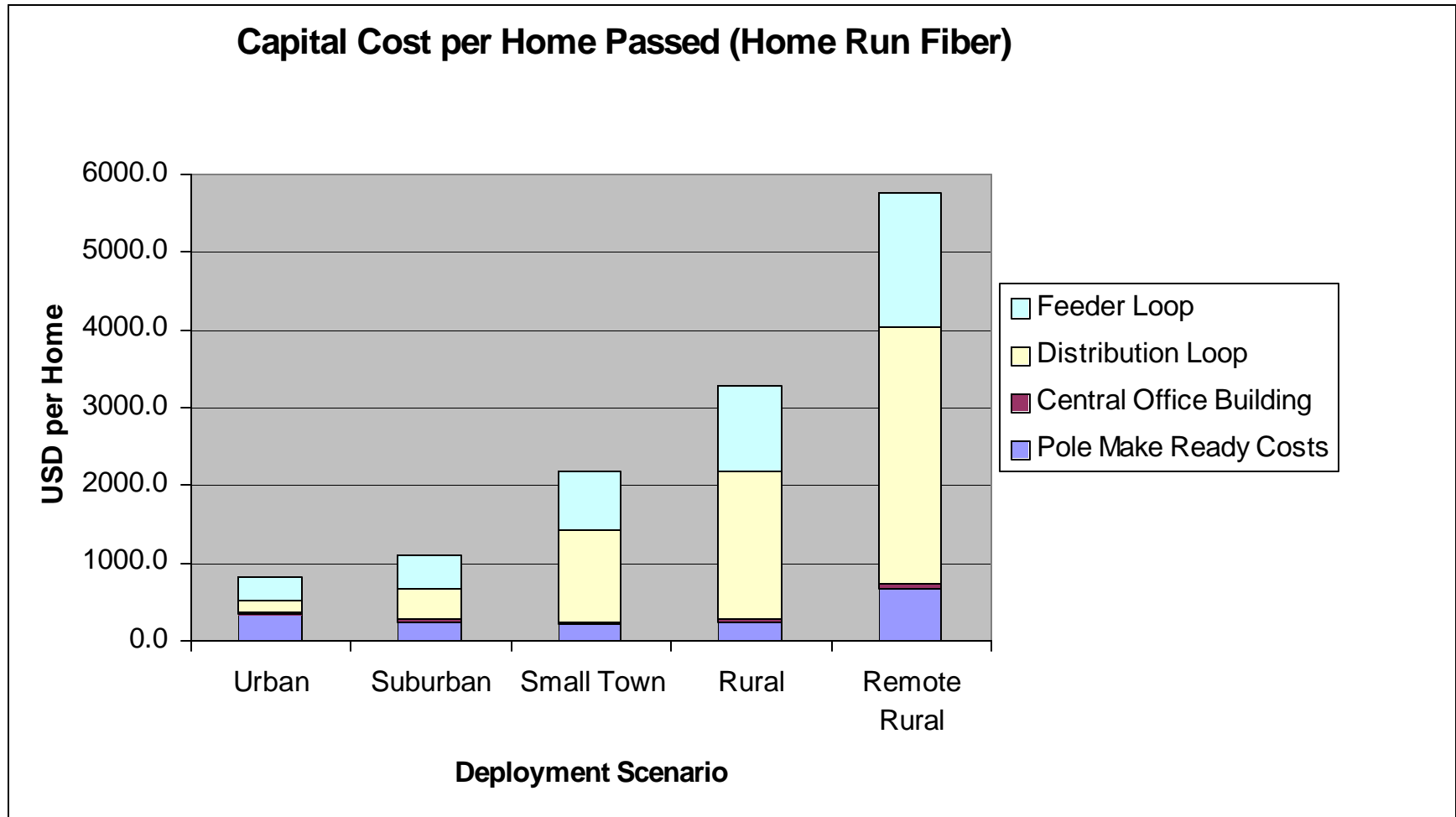
Capital Cost per Home Served Varies with Density

Curb-side PON deployment in Urban, Suburban, Small Town, Rural and Remote Rural Areas

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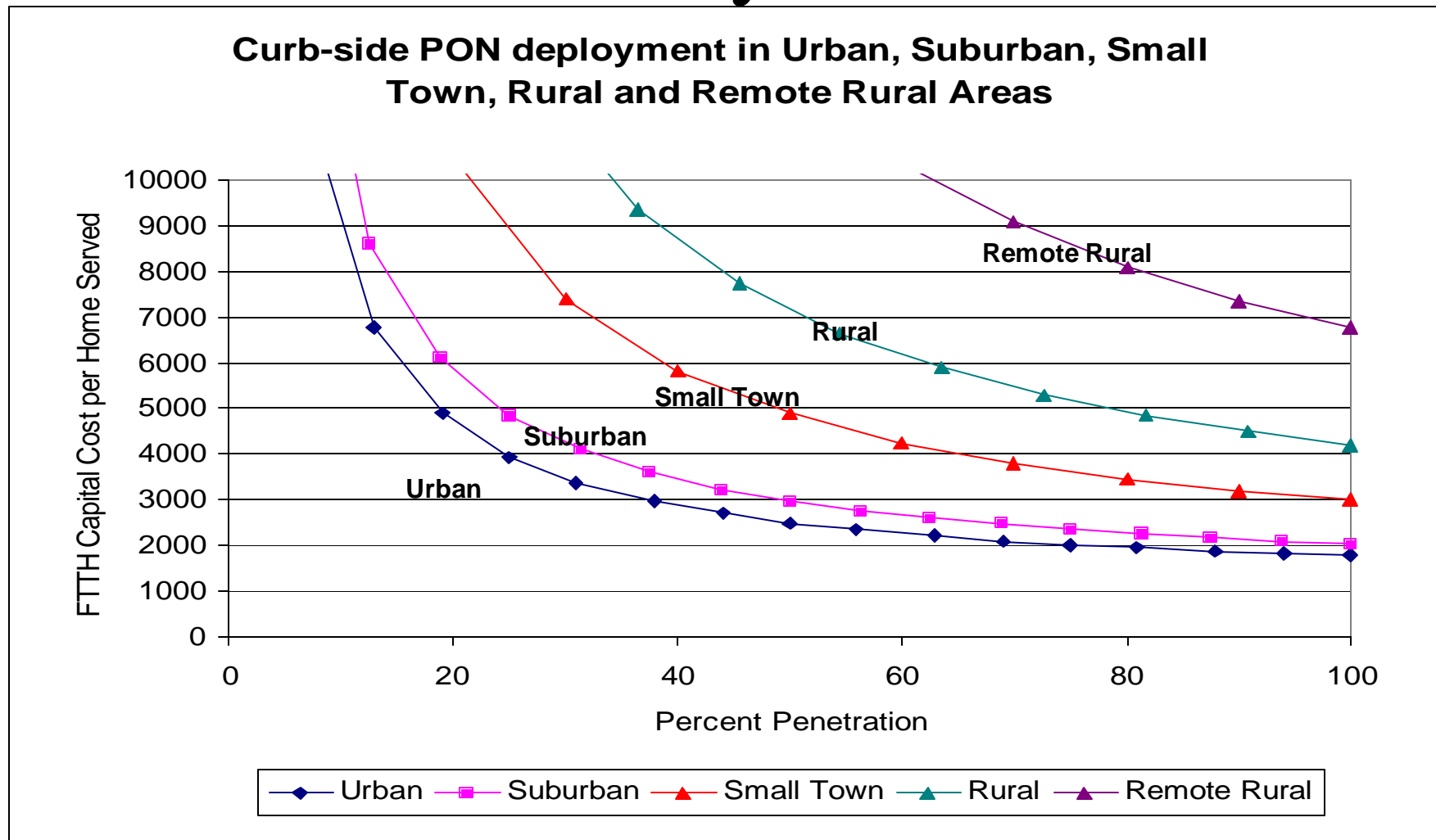
How Does Architecture Affect Competition?

- Facilities based Competition is unlikely as FTTH is a decreasing cost industry
- Wavelength based competition is infeasible in the near future
- Data Link Layer Competition and competition in Broadcast video is easy in Home Run architecture and hard in curb-side PONs
- "Open Access" Competition in Data, Voice and Switched Digital Video is unaffected by fiber plant architecture
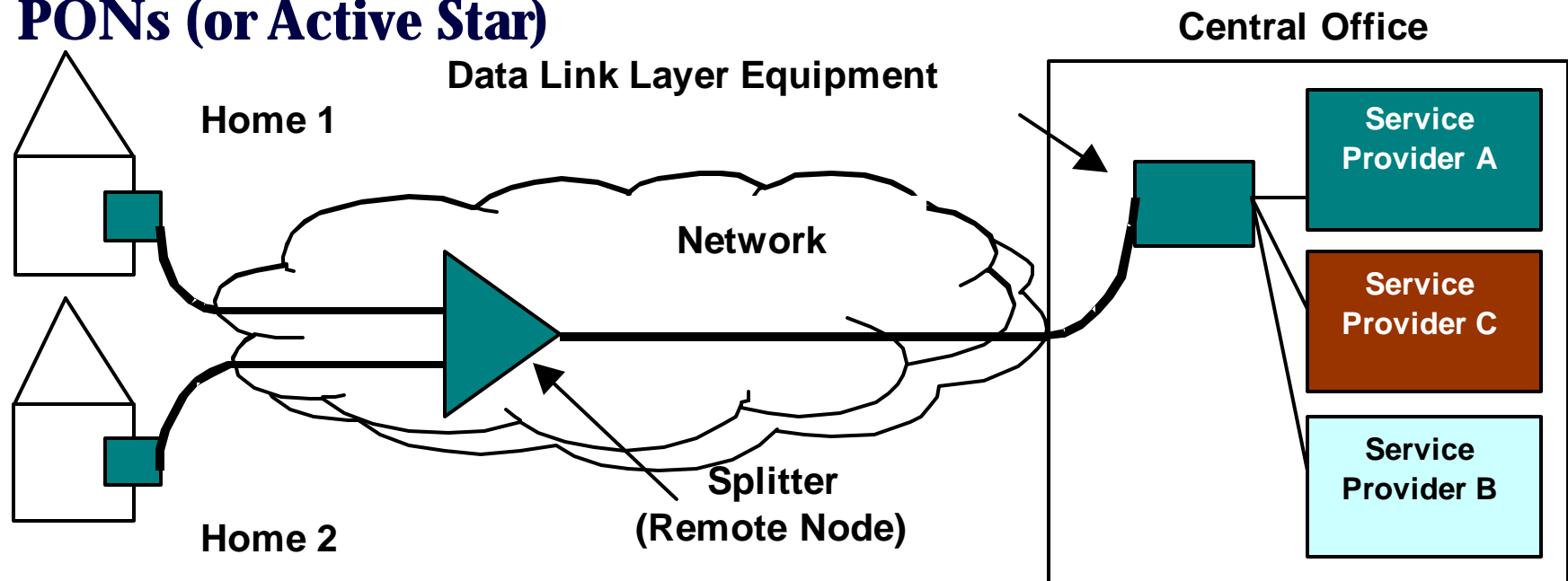
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Non facilities based Competition in Home Run Fiber

- ✎ **Physical plant unbundling is possible**

- ✎ **Individual Fiber can be rented out as a UNE**

Central Office

Home 1

Network

Service Provider A

Service Provider C

Service Provider B

Home 2

Data Link Layer Equipment
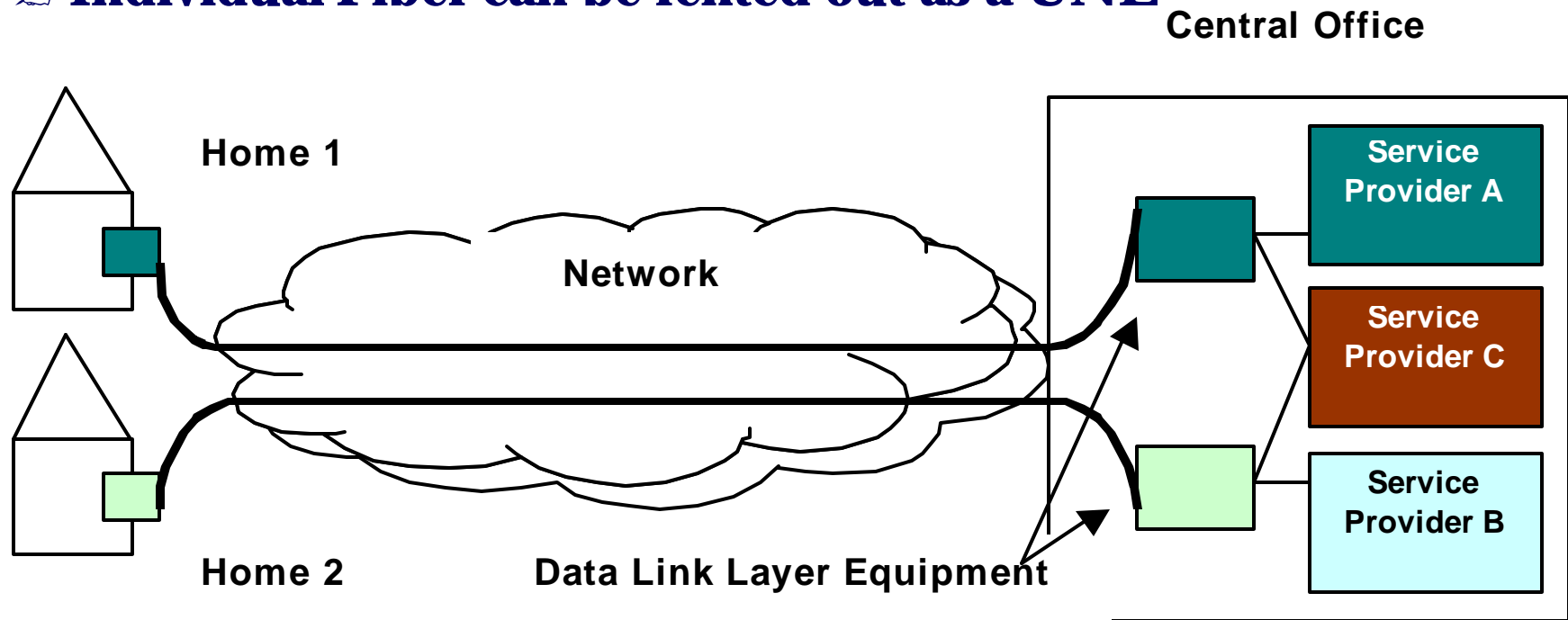
✎ **Home Run Fiber is compatible with Competition at *both* the Data-Link layer and in Higher layers services (Open Access)**

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Non facilities based Competition in Curb-side PONs and Active Star

✎ **Physical Layer Unbundling is not possible in curb-side PONs (or Active Star)**

Data Link Layer Equipment

Central Office

Home 1

Network

Service Provider A

Service Provider C

Service Provider B

Splitter (Remote Node)

Home 2

✎ **Curb-side PONs (and Active Star) fiber plant architectures do not support competition at the data-link layer or in broadcast video delivery; they can support *open access* competition at the services layer (including *switched* video)**

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Rethinking PONs

- **A curb-side PON is not the only type of PON**

- **What happens to costs when fiber layout groups multiple splitters at one location?**
  - Splitters grouped at an *Optimal Fiber Aggregation Point* (OFAP)
    - Multiple feeders to the OFAP
    - Per home distribution fiber from the OFAP

# Optimal Fiber Aggregation Point - OFAP

Neighborhood 1

Central Office Infrastructure

Splitter 1

Central Office OLT Equipment

Splitter & OLT to be deployed as needed

Central Office OLT Equipment

Splitter 2

Aggregation point

Neighborhood 2
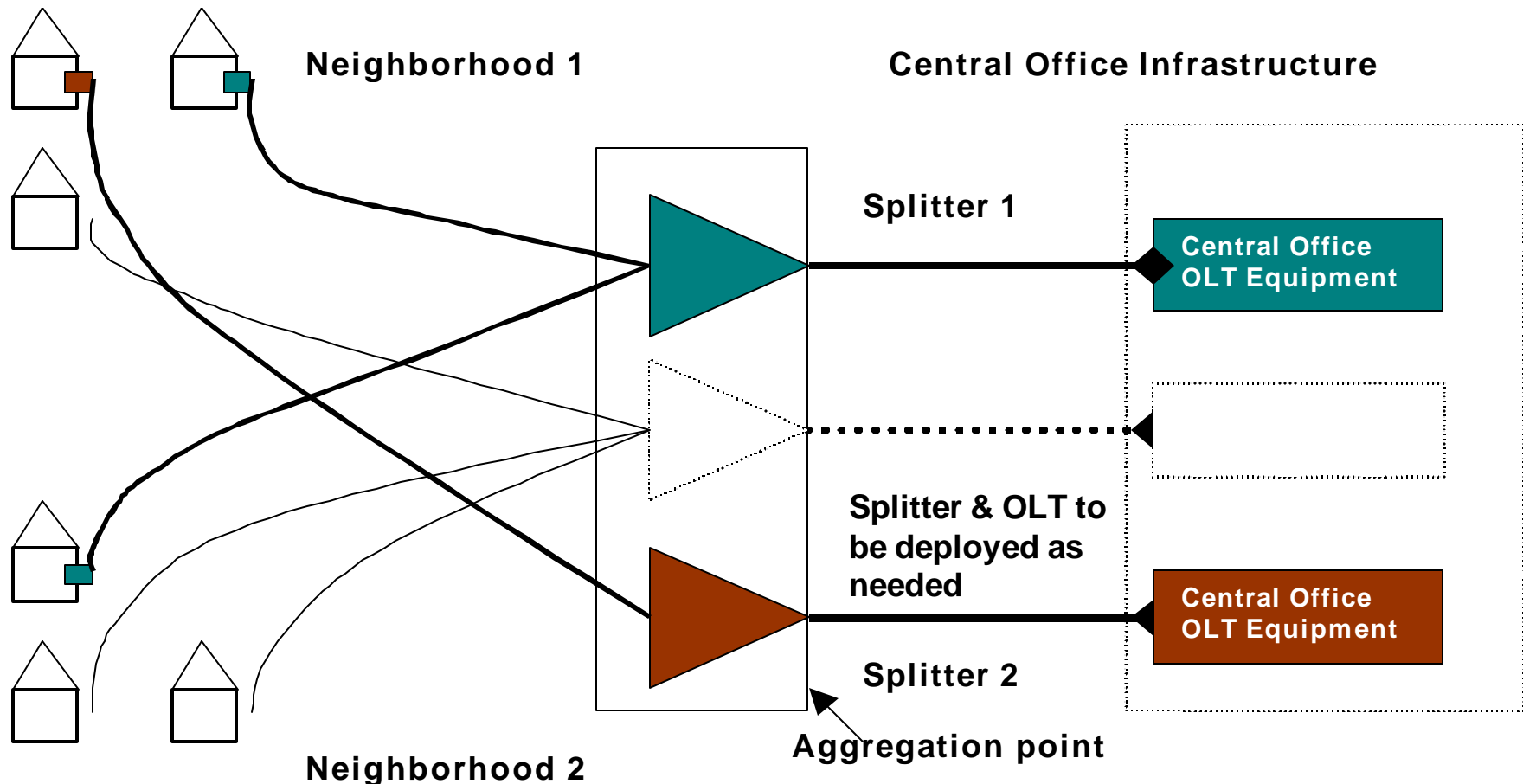
- Higher utilization of Splitter and OLT ports
- Electronics can be deployed by competitive providers

OFAP Limiting Case:
The 'Home Run PON'

Neighborhood 1

Central Office Infrastructure

Splitter 1   **PON1**

Central Office OLT Equipment

Splitter & OLT to be deployed as needed

Central Office OLT Equipment

Splitter 2   **PON2**

Neighborhood 2
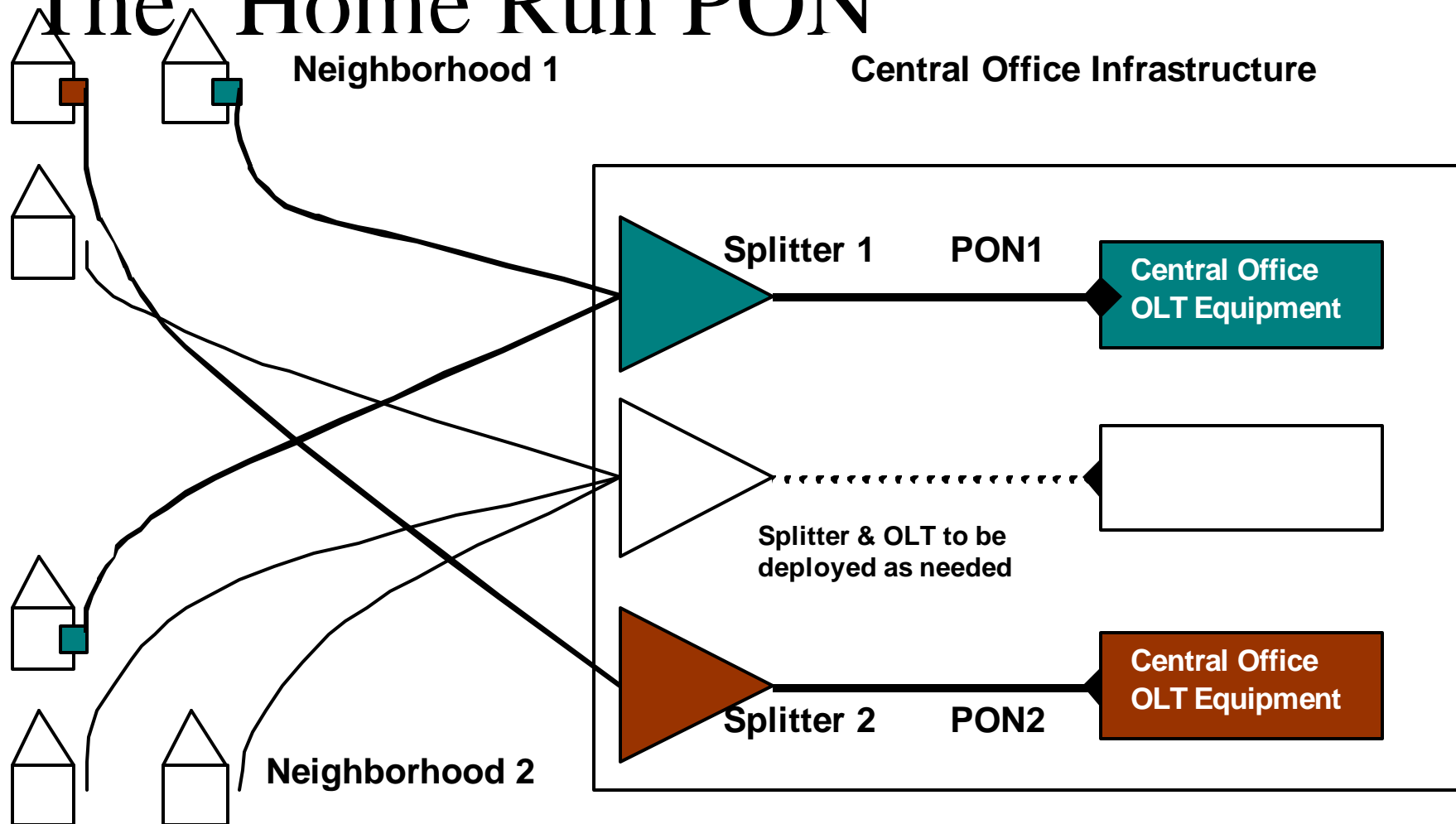
- Preserves PON advantage of shared OLT ports
- Deploy splitters, OLTs only as needed
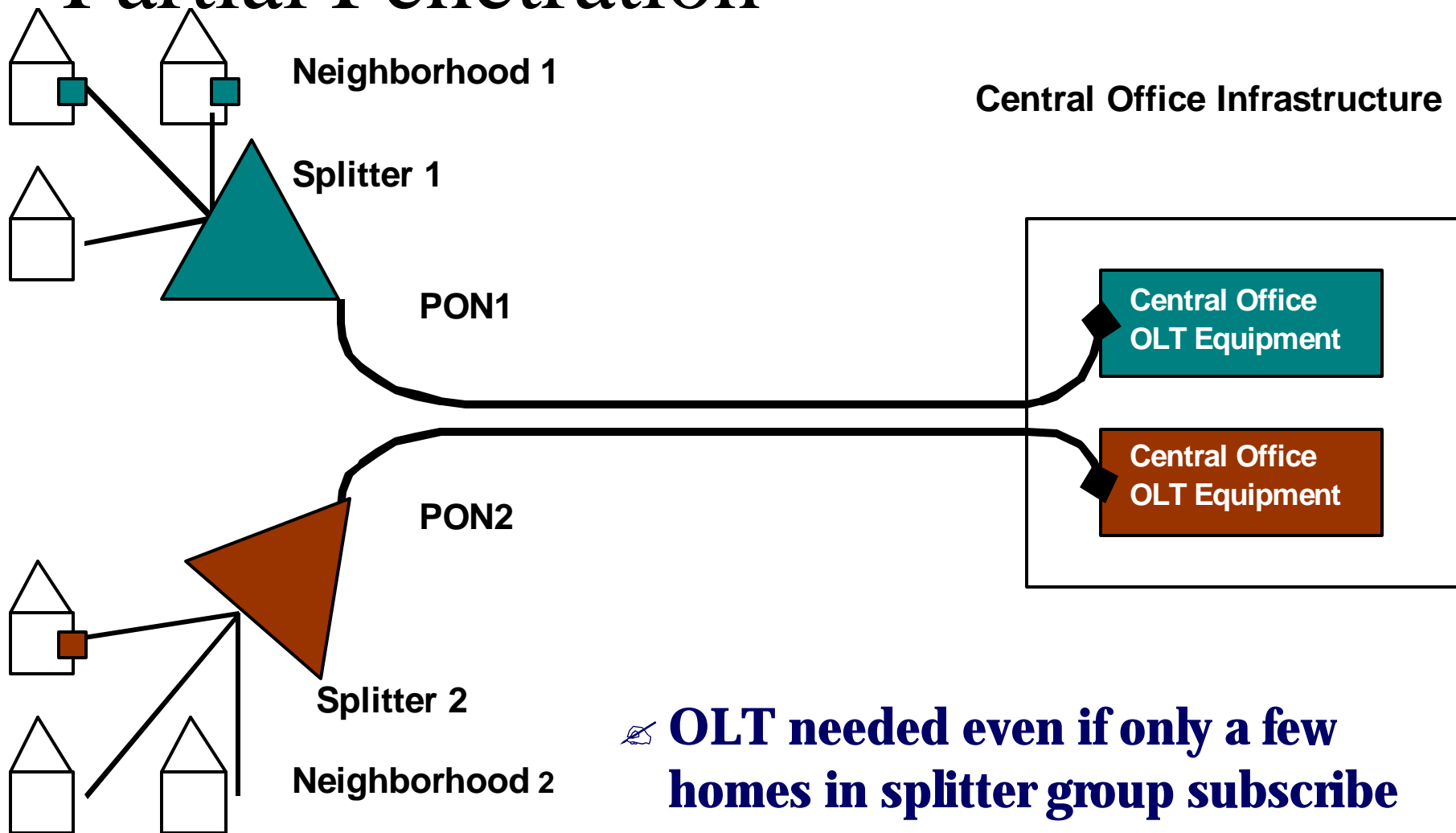- Electronics can be deployed by competitive providers

Economics of OFAP Architectures
(Urban deployment, 100% penetration)
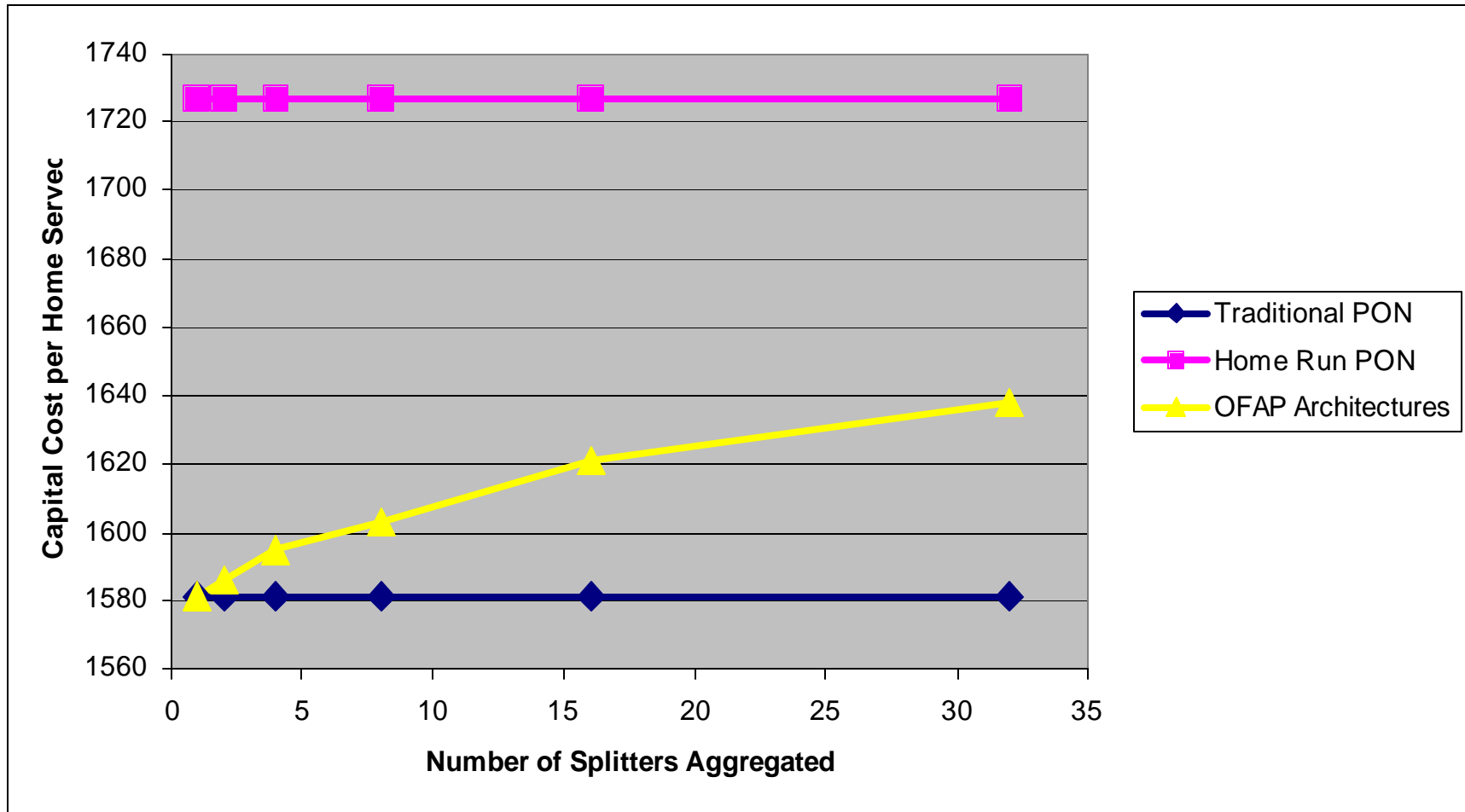
Initial Capital Costs Are Not the Whole Story

- What happens when deployment is phased in over time?
- How can technology evolve?
- What about high demand users wanting dedicated fiber?

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A Curb-side PON Deployment with Partial Penetration

Neighborhood 1

Central Office Infrastructure

Splitter 1

PON1

Central Office OLT Equipment

Central Office OLT Equipment

PON2

Splitter 2

Neighborhood 2

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? **OLT needed even if only a few homes in splitter group subscribe**

What happens when Deployment is phased in over time?

- **Economic benefits accrue from delaying equipment deployment as customers sign up**
  - Discounting of future expenditures
  - Equipment costs decline over time
- **NPV of Capital Cost per Home Served depends on assumed rate of penetration**
- **OFAP architectures provide greater opportunity for flexible service roll out**
- **Assumptions**
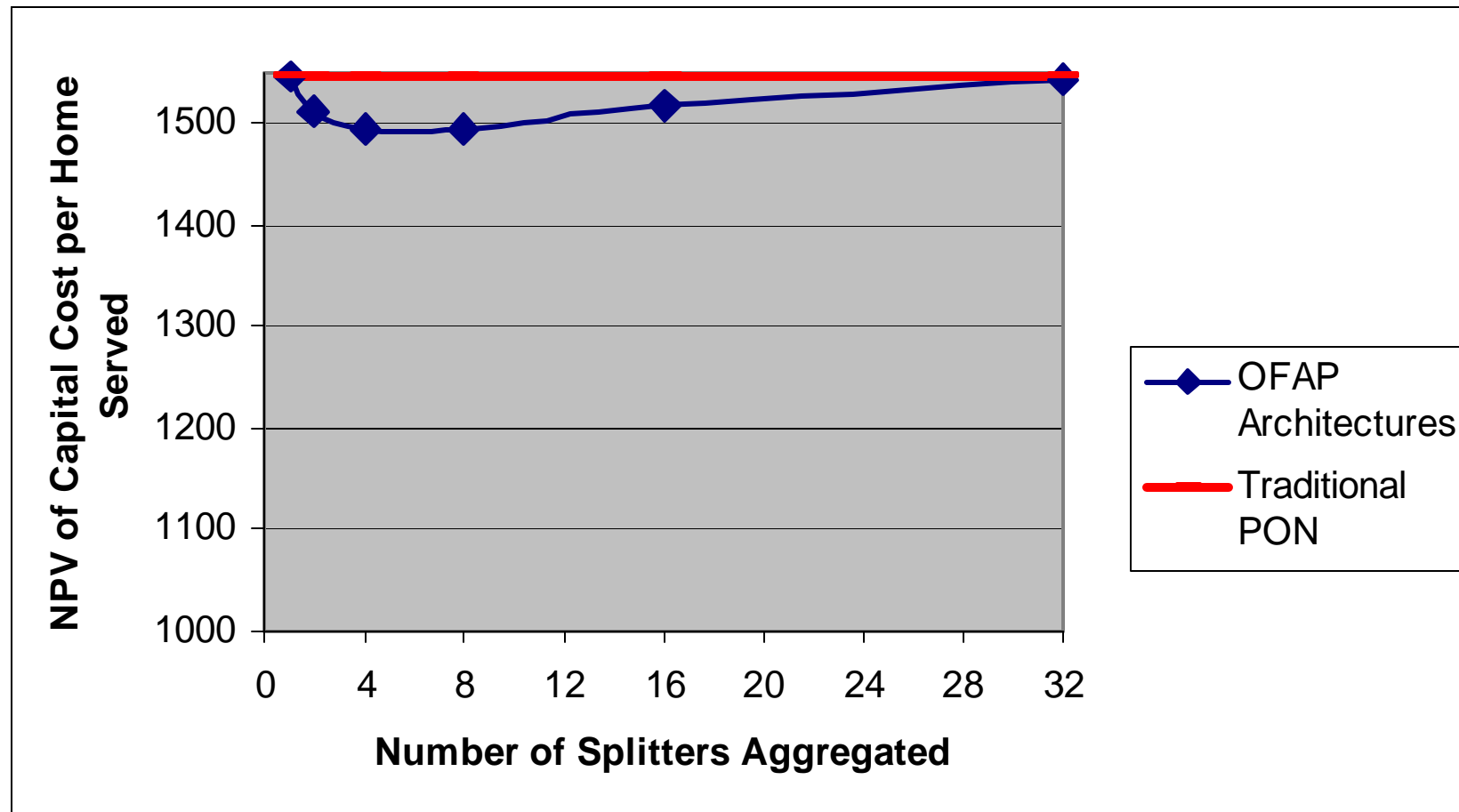 - High, Medium and Low Rates of Market Penetration
  - Discount Rate of 12%

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Modeling Market Penetration
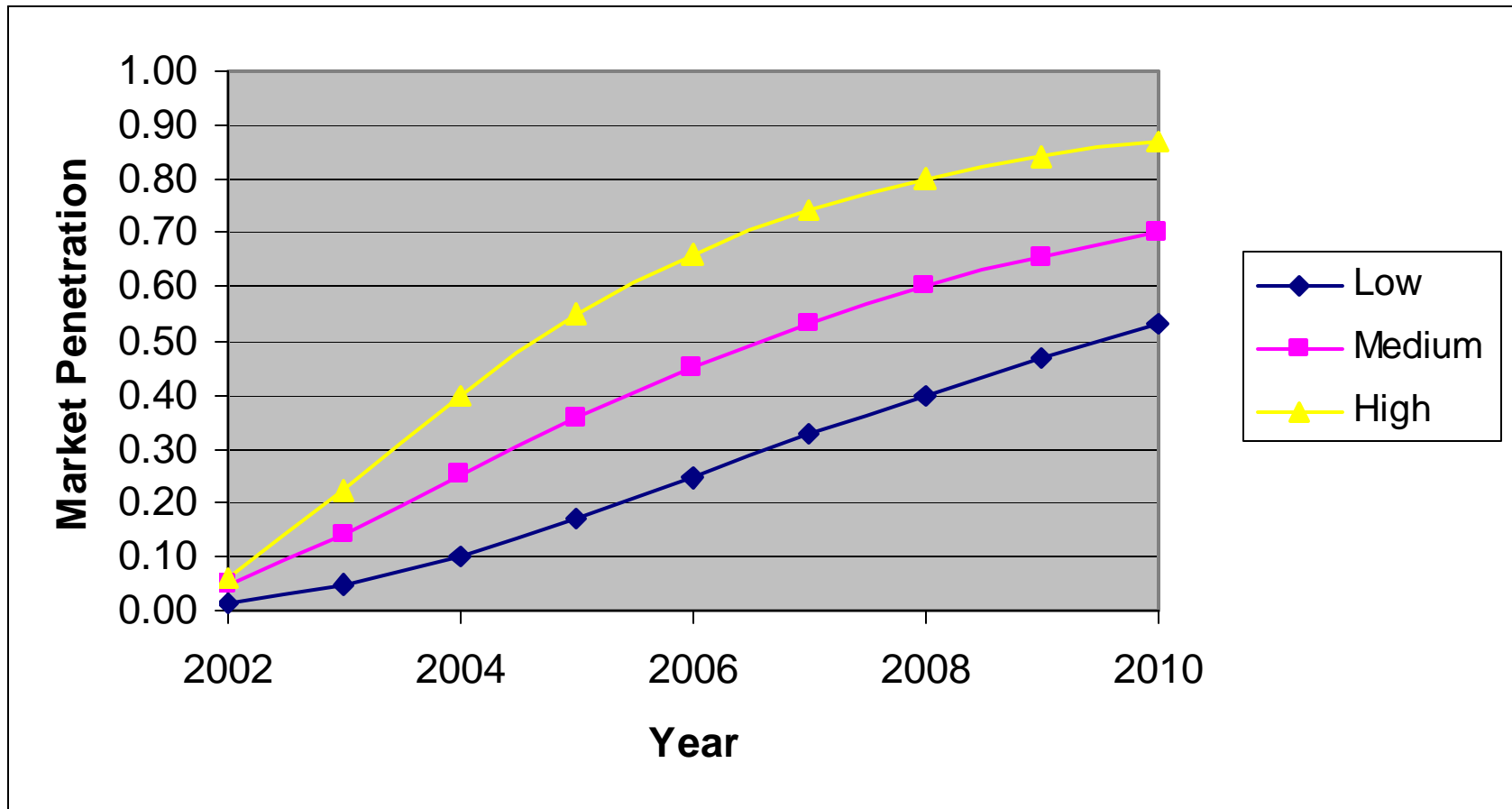
Economics of OFAP Architectures

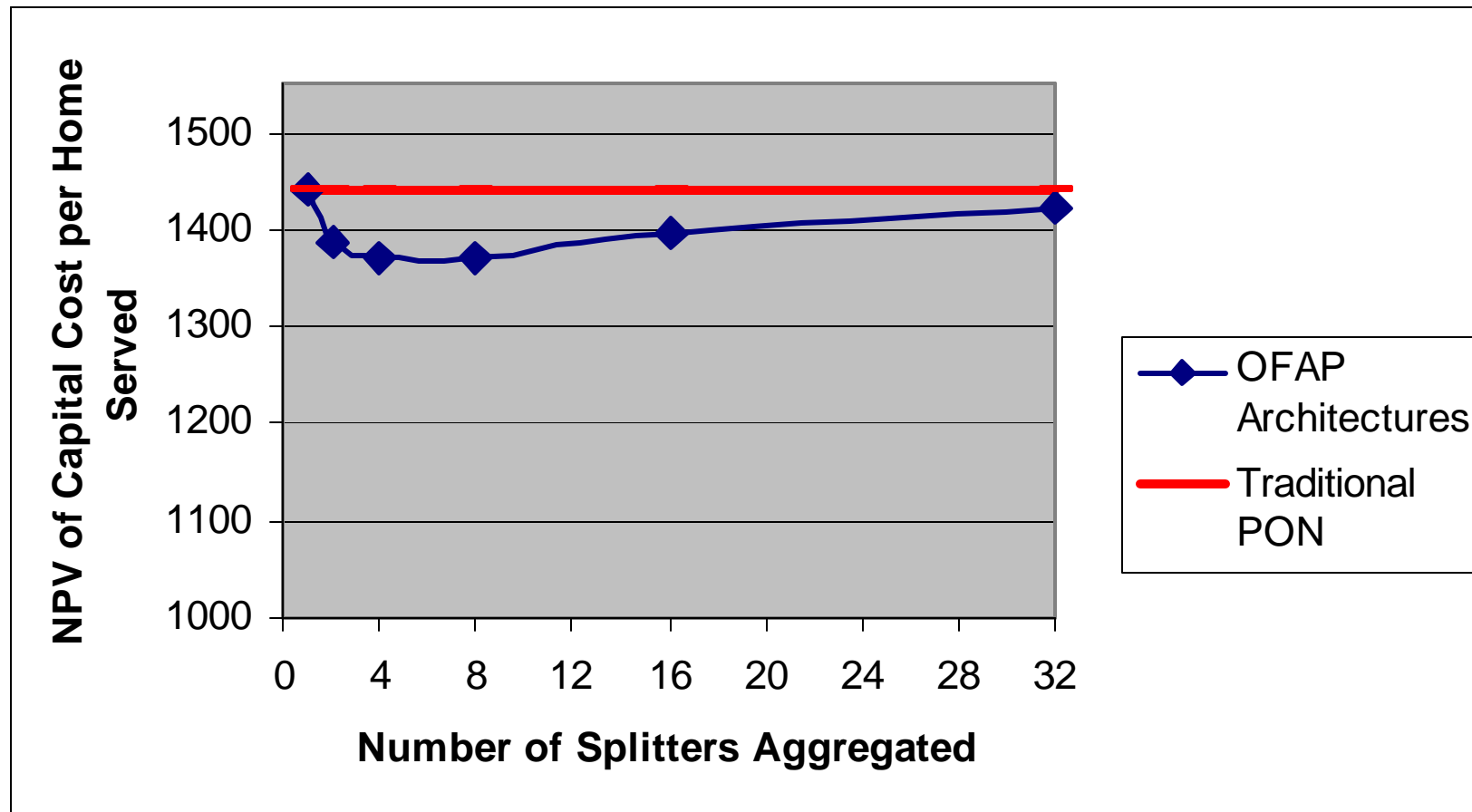Low Market Penetration Rate (10% by 2004; 40% by 2008)
No Decline in Equipment Costs

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Economics of OFAP Architectures
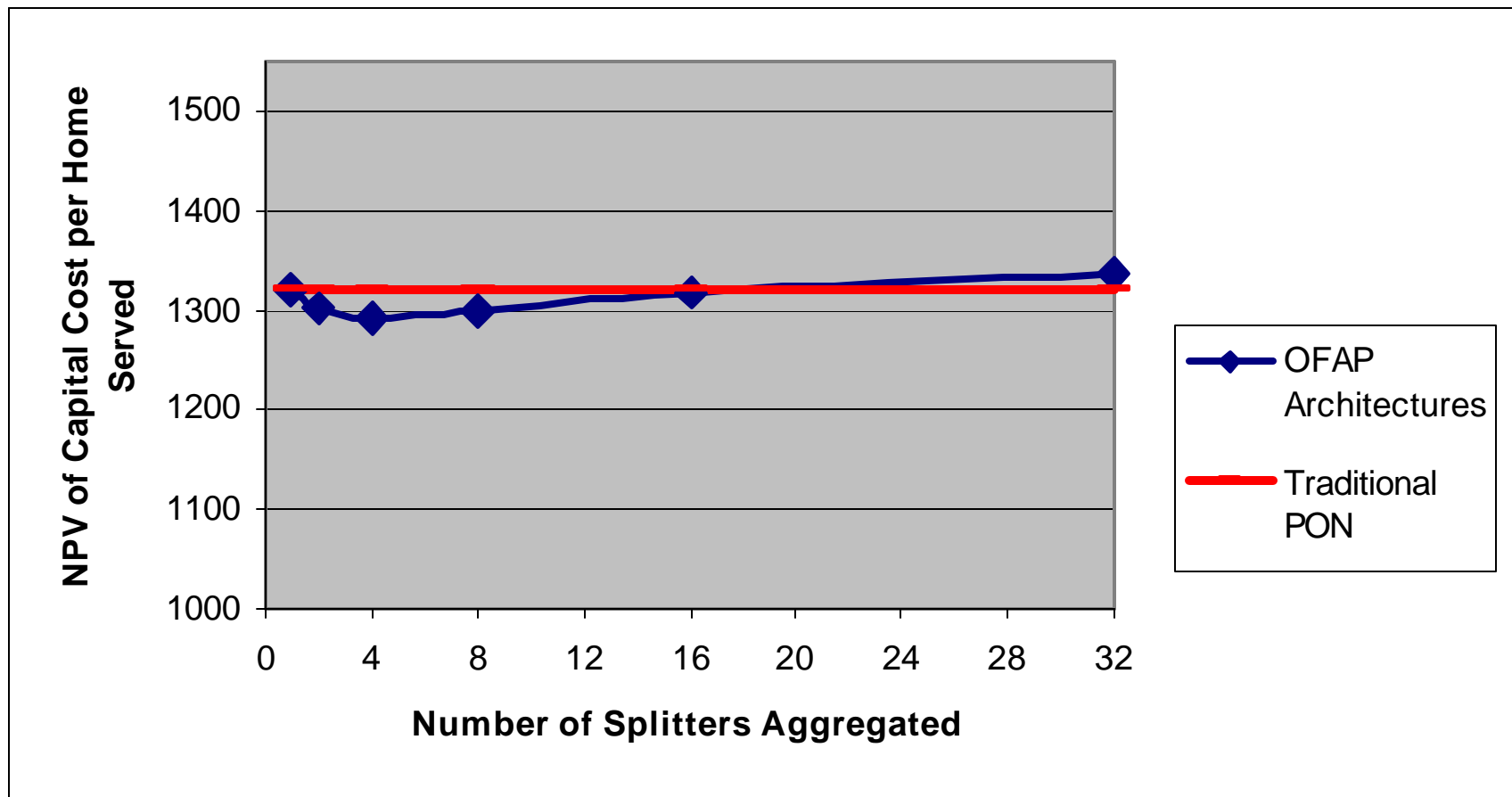
Low Market Penetration Rate (10% in 2004; 40% in 2008)
Equipment Costs decline @ 10% per year

Economics of OFAP Architectures
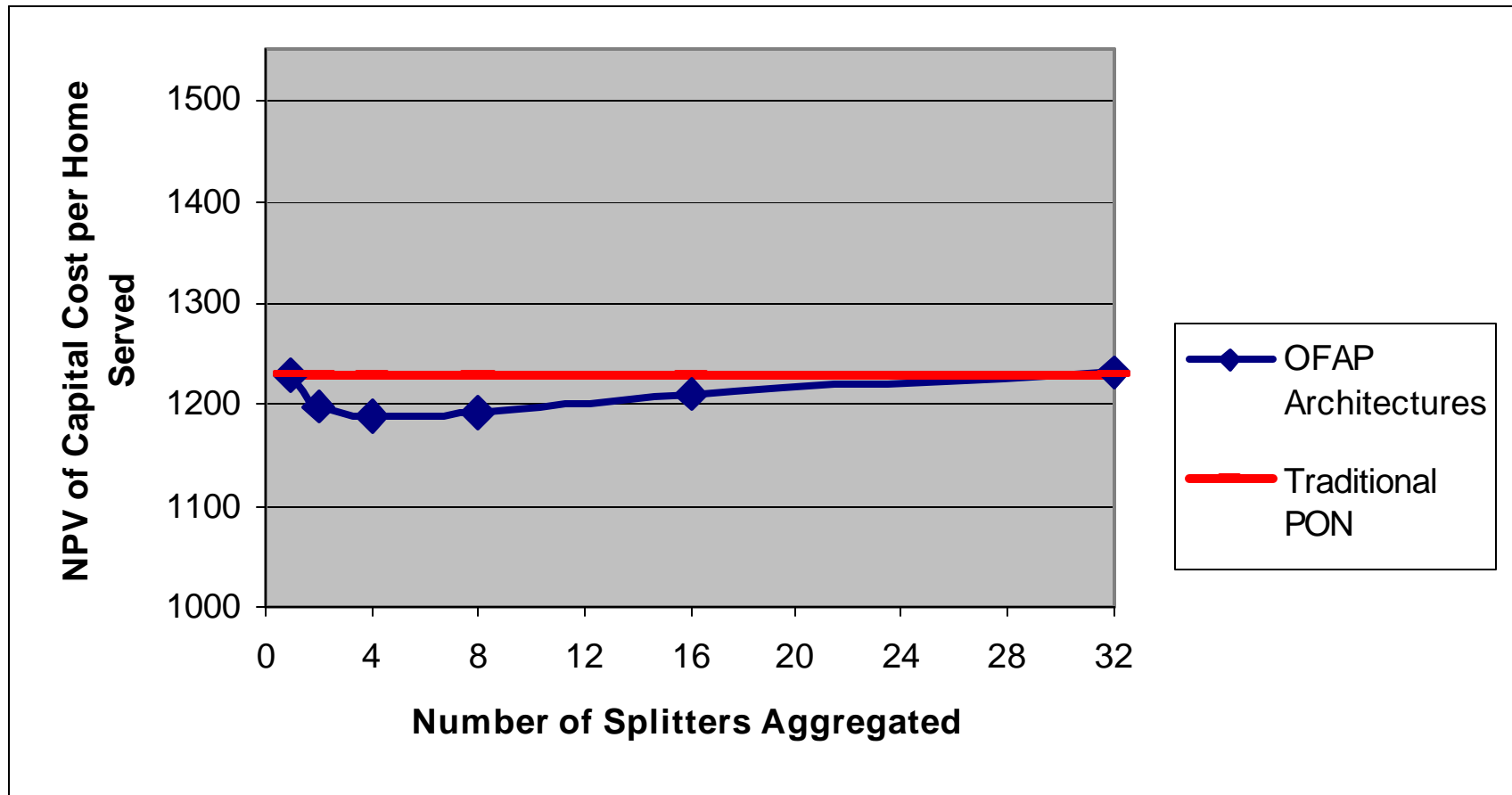Medium Market Penetration Rate (25% by 2004 and 60% by 2008)
No Decline in Equipment Costs

Economics of OFAP Architectures

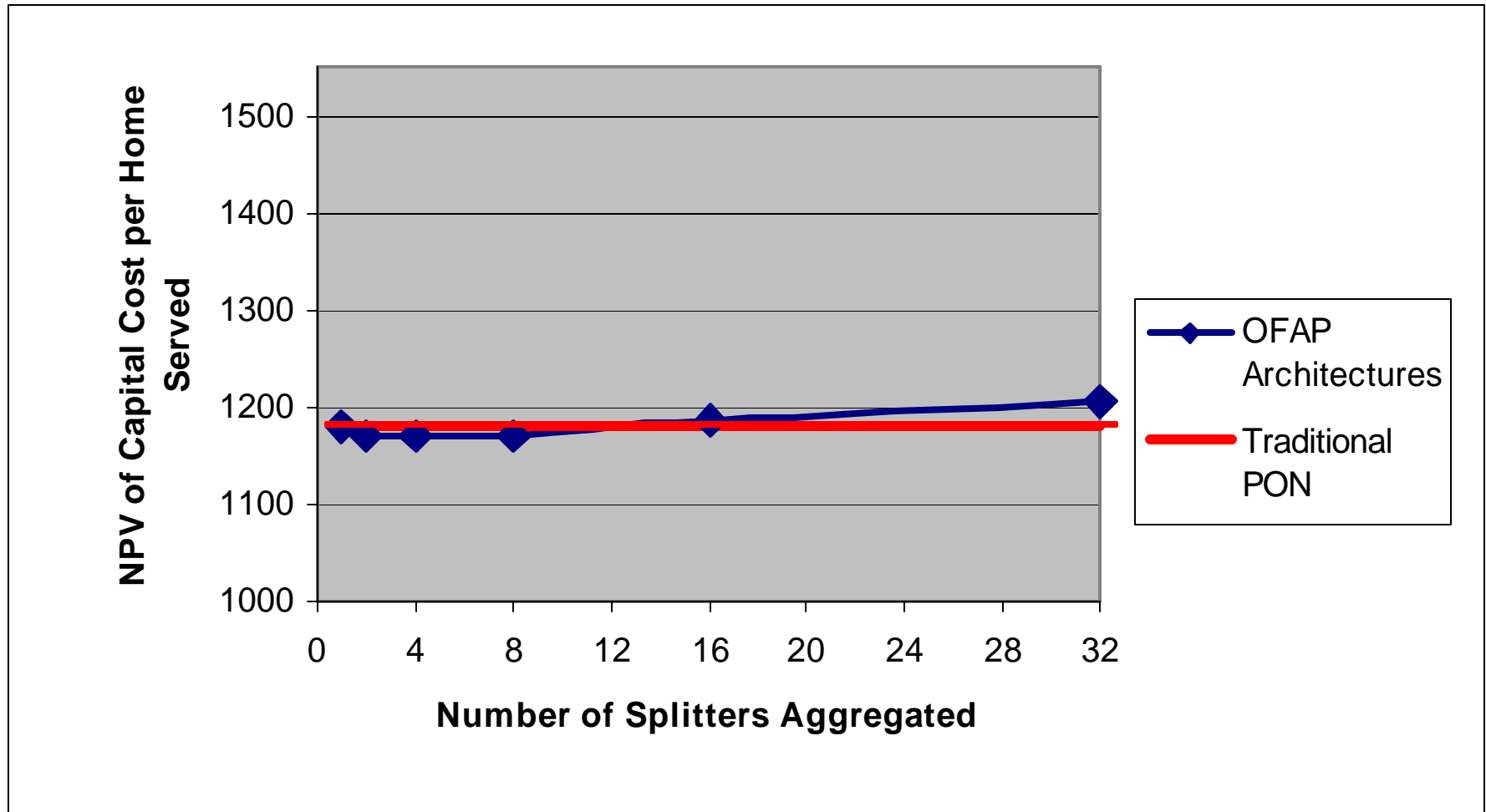Medium Market Penetration Rate (25% by 2004 and 60% by 2008)
Equipment Costs decline @ 10% per year

Economics of OFAP Architectures

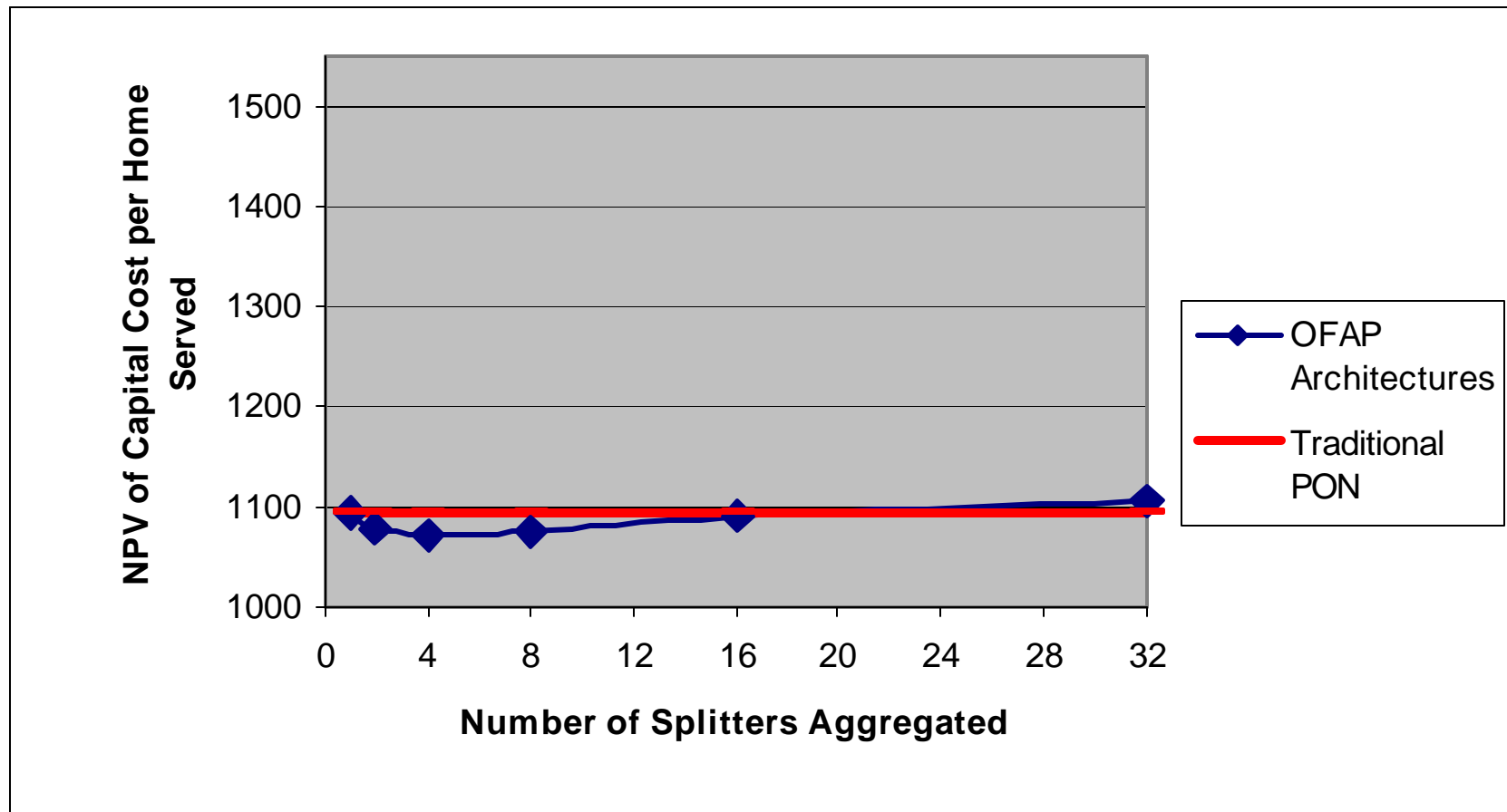High Market Penetration Rate (40% by 2004 and 80% by 2008)
No Decline in Equipment Costs

Economics of OFAP Architectures

High Market Penetration Rate (40% by 2004 and 80% by 2008)
Equipment Costs decline @ 10% per year

Real Option to Scale Bandwidth..

- PONs (and Active Stars) impose bandwidth sharing
- Incremental ost of Home Run fiber may be viewed as a *Real Option* for unlimited bandwidth to any subscriber
- OFAP with spare feeders provides a lower cost real option for dedicated fiber to a subscriber

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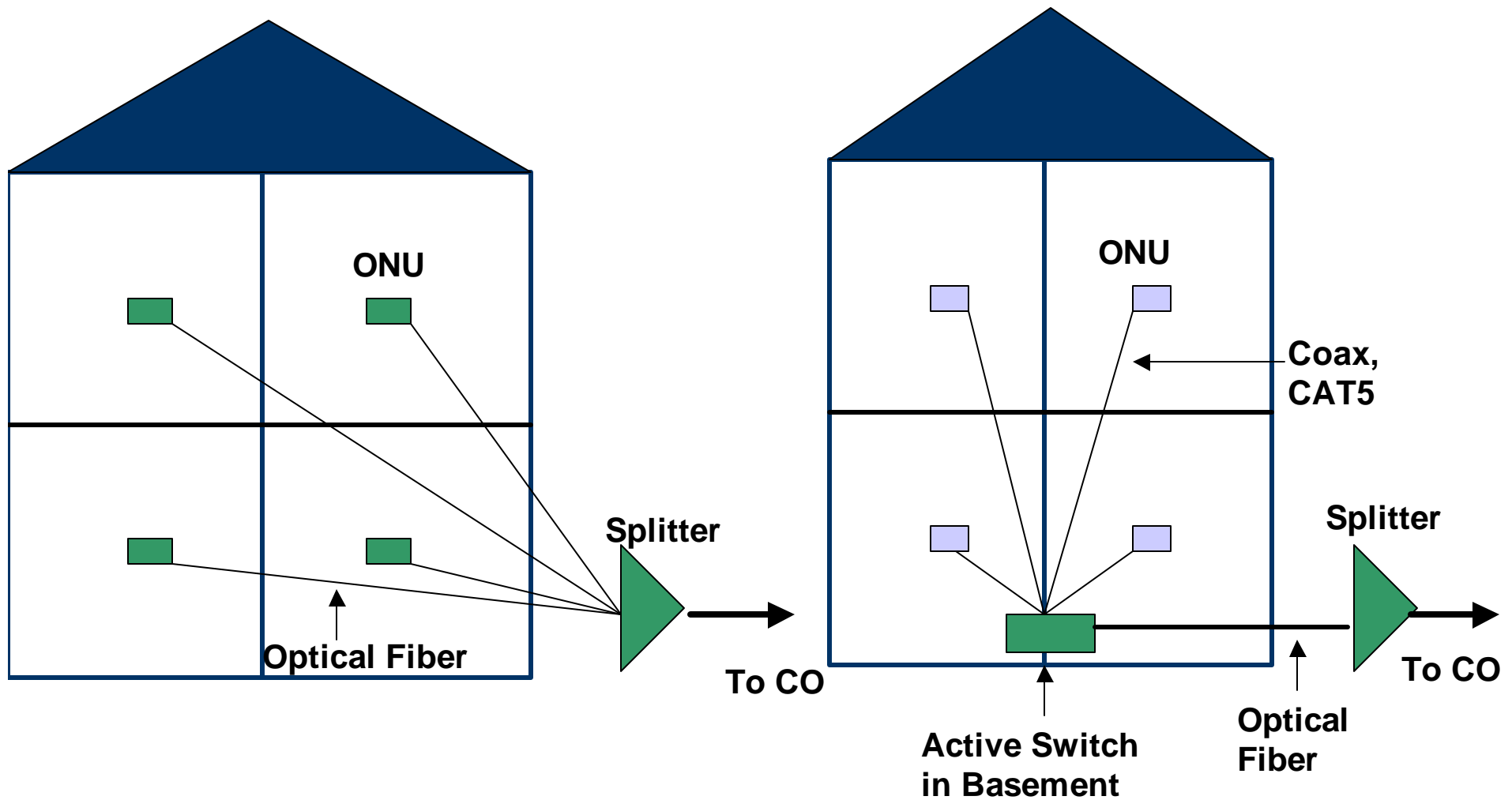
Which is Truly the Low-Cost Architecture?

- **Is it the curb-side PON which has lower initial first capital costs?**
- **Or is it the OFAP PON which**
  - Has lower NPV cost
    - Saves on phased OLT deployment
    - Saves on feeder fiber overprovisioning needed to serve future large-demand users
  - Facilitates technological evolution
  - Drives competition
- **Even if OFAP architectures had marginally higher NPV costs than a curb-side PON, the benefits of data-link layer competition should drive down overall service costs**

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Caveats: MDU Deployments

ONU

ONU

Coax, CAT5

Splitter

Splitter

Optical Fiber

To CO

To CO

Active Switch in Basement

Optical Fiber

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Problem of MDUs

- **Unbundling is not possible in a PON for MDU deployments where the fiber is to the basement with an Active Split in the basement and CAT5 or Coax running into each unit**

- **65% of homes in the United States are Single Family-Single Subscriber Homes (American Housing Survey, 1999)**

Conclusions

- **Optimal Fiber Aggregation Points (OFAP) lead to:**

  - Lower NPV Costs and greater Flexibility of Service Roll-out

  - Enables Physical Plant unbundling of a PON and UNE based competition leading to per subscriber choice of Data-Link Layer Technology

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